A SEVERE WEATHER CLIMATOLOGY FOR THE WFO RALEIGH, NC COUNTY WARNING AREA

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INTRODUCTION:

The National Weather Service's (NWS) primary responsibility is the "protection of life and property". NWS Weather Forecast Offices (WFO) are tasked with issuing severe weather watches and warnings for their areas of responsibility or County Warning Area (CWA). For Central North Carolina, the combination of abundant low-level moisture from both the Atlantic Ocean and Gulf of Mexico along with frontal boundaries that interact with this moisture often set the stage for strong to severe thunderstorm development. As a result, WFO Raleigh's CWA experiences a wide variety of weather phenomena, including severe thunderstorms that produce tornadoes, large hail, and damaging wind gusts. A local severe weather climatology is essential for determining severe weather risk. This study provides a severe weather climatology for Central North Carolina. Frequency and magnitude of severe weather events along with seasonal, time of day, topographical and demographic influences are highlighted.

DATA AND METHODOLOGY

Data used for this study includes tornado, hail, and thunderstorm wind gust reports for each county in the Raleigh CWA, between January 1, 1950 and December 31, 2002. NOAA's NWS Storm Prediction Center (SPC) in Norman, OK and NOAA's National Data Center (NCDC) in Asheville, NC provide online access to documented severe weather events. All times are referenced to Eastern Standard Time (EST).

As defined by the NWS, a severe local storm is one that is sufficiently intense to threaten life and/or property, including thunderstorms with large hail, damaging wind, or tornadoes. More specifically, severe thunderstorms (National Weather Service 1995) are further defined as a storm that meets one or more of the following criteria:

- A tornado
- Hail three-quarters of an inch in diameter or larger
- Wind of at least 50 knots (58 mph) or wind which causes damage, including trees or power lines blown down

COUNTY WARNING AREA TOPOGRAPHY AND DEMOGRAPHICS

Topography

WFO Raleigh's CWA (Figure 1) is comprised of 31 counties including 10 counties in the northern piedmont, 5 counties in the central piedmont, 4 counties in the southern piedmont, 4 counties in the northern coastal plain, 3 counties in the central coastal plain and 5 counties in the southern coastal plain. Raleigh's CWA covers 16,459 square miles and includes the metropolitan areas of Raleigh/Durham and Chapel Hill (Triangle), Greensboro/Winston-Salem and High Point (Piedmont Triad), Rocky Mount/Wilson and Fayetteville/Fort Bragg.

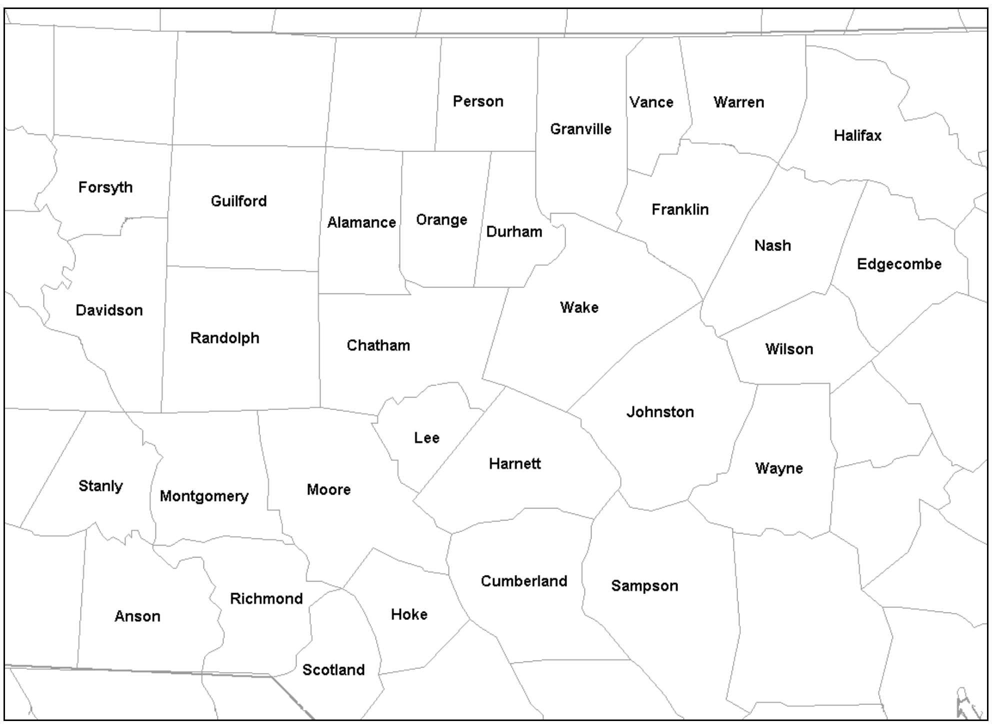

Figure 1: Raleigh's CWA.

Topography is a contributing factor in the initial development of convective storms. The two principal topographic regions that encompass Raleigh's CWA are the piedmont and coastal plain regions. The Piedmont is characterized by rolling hills and soils that are mainly loam and clay-loam. A notable increase in elevation occurs west of the "fall line" which runs roughly along Interstate I-95. The "fall line" is the dividing line between the piedmont and coastal plain. The elevations generally range from 250 feet along the "fall line" to elevations of approximately 1100 feet in the extreme western part of the CWA . Conversely the coastal plain is characterized by flat land with a variety of soil types that are soft sediment in nature. The elevation generally ranges from 50 feet over the extreme eastern part of the CWA to approximately 250 feet over the western boundary or near the "fall line". It is here along the "fall line", where the variety of soil types of the coastal plain, are bounded by the piedmont clay-loam soil of the piedmont. Within the coastal plain is a smaller topographic area called the "Sandhills", where sand is the primary soil type. On sunny days, as the sun heats the earth's surface, the airmass over the Sandhills, heats up more quickly than the air over the surrounding area. It is the differences in these soil types that create differential heating of the surface. While this phenomena alone, does not determine the severity of thunderstorms, it does have a significant impact in defining the areas that are more or less likely to experience convective storms.

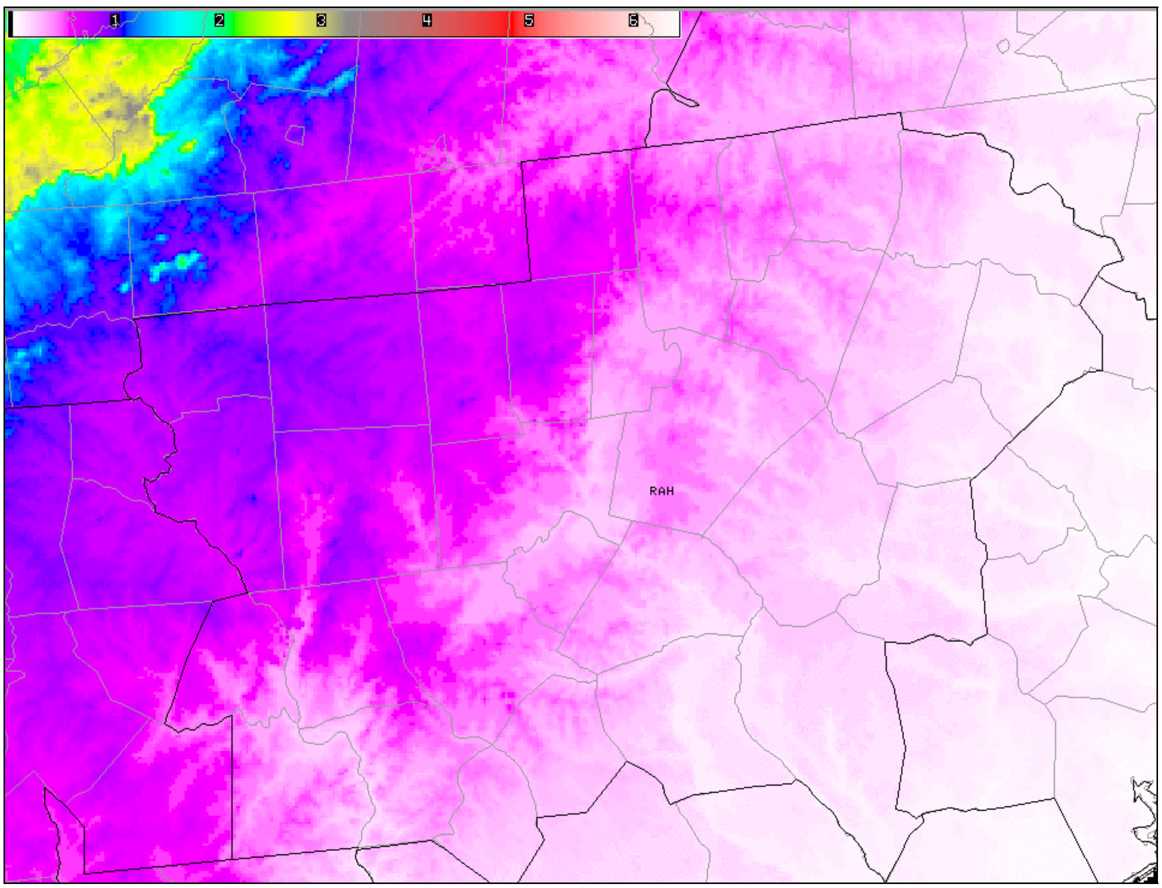

Figure 2: Topography map of Raleigh's CWA. **Elevation: thousands of feet (kft)**

Demographics

One statistical bias that appears in the data and should be noted is population density. Population statistics were obtained from the 2000 Census.

The population of the WFO Raleigh's CWA is roughly 3.7 million people (Census 2000). WFO Raleigh's CWA is home to 7 of the 10 largest municipalities in the state. Although the CWA contains these large population centers, the CWA has a low population density. Outside of these population centers, the CWA is mainly rural farmland or heavily forested, and contains sparse population. This uneven distribution of people across the CWA (Figure 3) can lead to skewing of observed severe weather events toward the more heavily populated locations (e.g., Wake County).

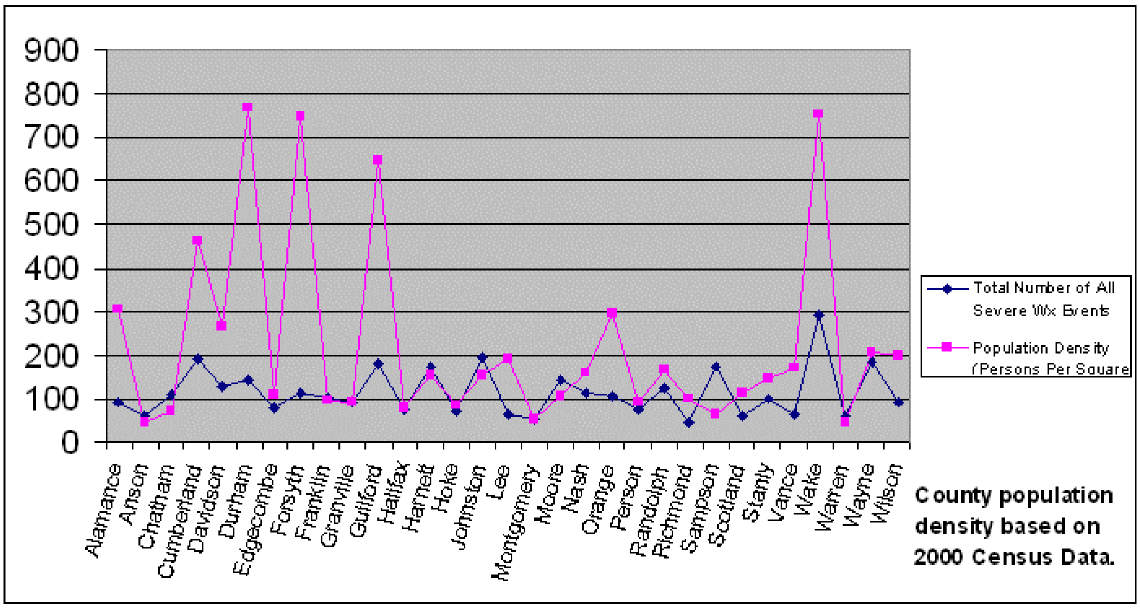

Figure 3: Comparison of county population to number of severe events reported from 1950-2002.

SEVERE WEATHER CLIMATOLOGY

Tornado Climatology

Monthly Distribution

The monthly distribution of tornadoes (Fig. 4) shows the Raleigh CWA can experience tornadoes any time of the year. However, tornadoes are most likely to occur during the spring, with the peak frequency in May. A total of 231 tornadoes occurred in the Raleigh CWA, of which, 51 tornadoes (22% of the total) were in May. Spring is the peak tornado season because the Raleigh CWA is still vulnerable to strong synoptic scale systems with jet stream influence. The occurrences of tornadoes decrease dramatically during the summer months

(June-August), as the jet stream migrates north. There is a pronounced, secondary peak of tornadoes in the fall. The secondary peak tornado season is explained by land-falling tropical systems and the southward extension of the jet stream to the southeast United States.

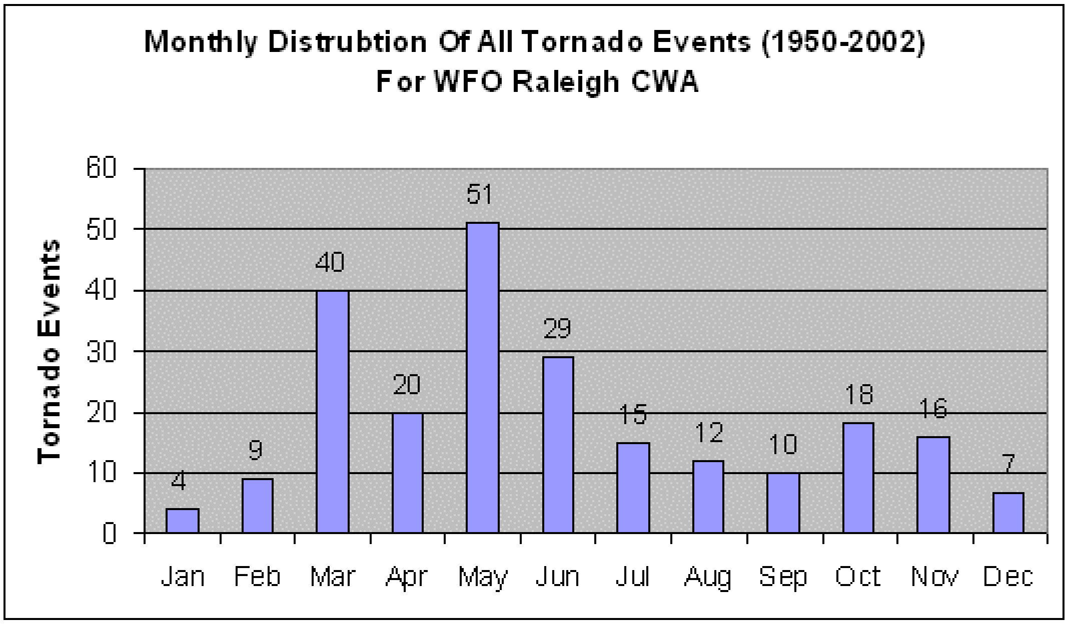

Figure 4: The monthly distribution of tornadoes (1950-2002) for WFO Raleigh CWA.

Hourly Distribution

Diurnal trends indicate an increase in tornadoes after the noon hour (Fig. 5). Over half of all tornadoes (56%) occur between the afternoon hours of 3 PM to 8 PM (EST). Tornado activity peaks in the late afternoon between 5 and 7 PM. Sixty-two tornadoes (27% of the total) occurred during the 5 PM to 7 PM time frame. The data shows a gradual decrease in the occurrence of tornadoes during the evening hours, and that tornadoes occur infrequently during the late night through early-to mid morning hours. Atmospheric instability is a key ingredient in the generation of tornadic storms and is usually maximized during the mid- to late-afternoon hours. Of interest, during the second peak season (September-November), the tornado events are more evenly distributed throughout the day.

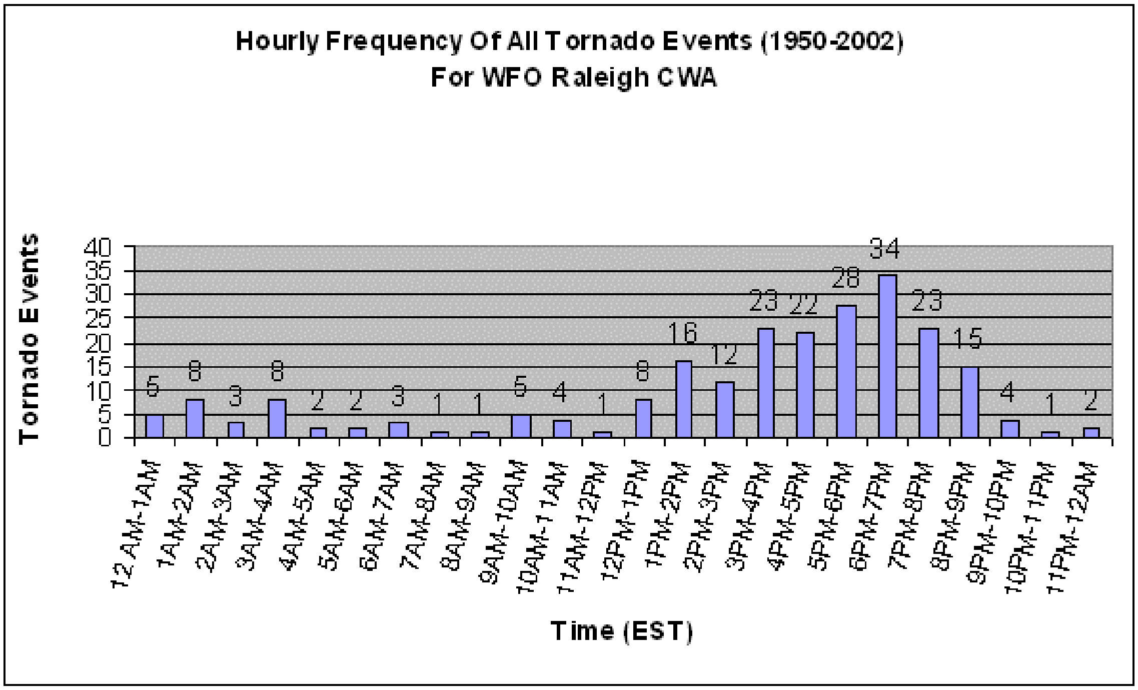

Figure 5: The hourly distribution of tornadoes (1950-2002) for WFO Raleigh CWA.

Intensity (Fujita Scale)

Tornado intensity was rated using the Fujita Scale (Table 1), which is based on the extent of the wind damage. Of the 231 tornadoes that were reported to have occurred in Raleigh's CWA, nearly three-quarters (165 or 71% of the total) were classified as weak F0 or F1 tornadoes (Fig. 6). Sixty-one tornadoes or 26% were rated strong (F2 or F3) and only 5 (2%) were rated as violent F4 tornadoes.
Of the five F4 tornadoes, three of the F4 tornadoes occurred in the March 28, 1984 Carolina Tornado Outbreak. There were no documented F5 tornadoes.

F-Scale	Intensity	Wind Speed	Type of Damage Done
F0	Gale Tornado	40-72 mph	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards
F1	Moderate Tornado	73-112 mph	Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off roads
F2	Significant Tornado	113-157 mph	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated
F3	Severe Tornado	158-206 mph	Roof and some walls torn off well constructed houses; trains overturned; most trees in forests uprooted
F4	Devastating Tornado	207-260 mph	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated
F5	Incredible Tornado	261-318 mph	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel reinforced concrete structures badly damaged

Table 1: Fujita Scale.

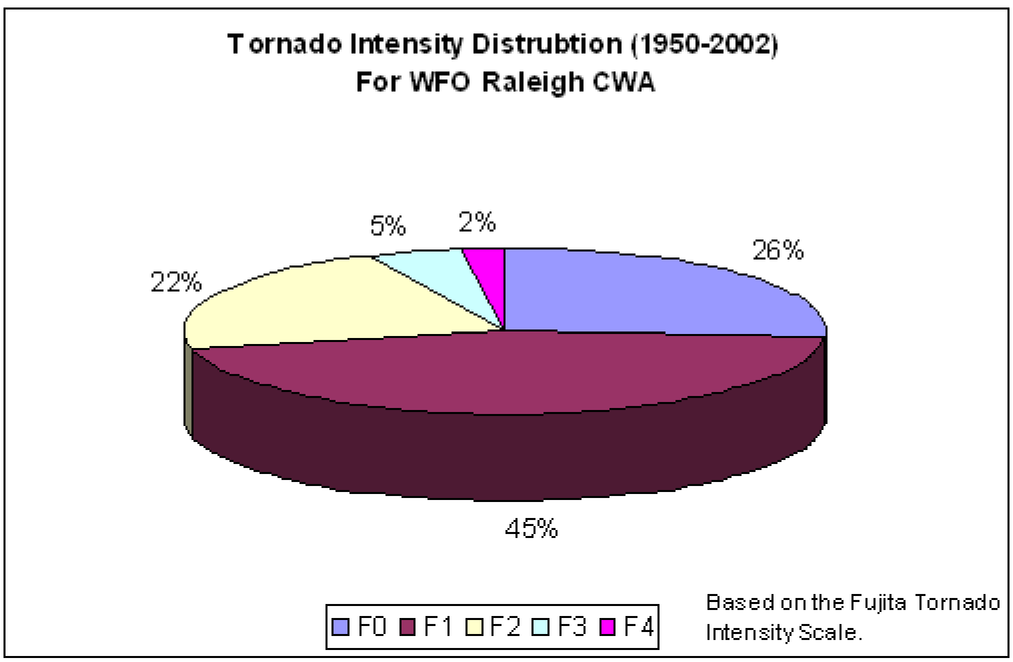

Figure 6: The tornado distribution by Fujita Scale (1950-2002) for WFO Raleigh CWA.

Hail Climatology

Monthly Distribution

The monthly distribution of severe hail (3/4 inch diameter or greater) indicates a strong inclination toward the spring season (Fig. 7). There is a sharp increase in the number of hail reports from March (131) to the peak month of May (325). The largest majority (78%) of the hail events occur during the months between April and July. There is a significant decrease in thunderstorms that produce hail during the transition from summer to fall (26 events in Sept. compared to 9 events in Oct.). The four month period between November and February is very inactive (14 events). The peak occurrence of hail in spring is largely due to the combination of relatively warm near surface temperatures with freezing temperatures in the mid levels of the atmosphere.

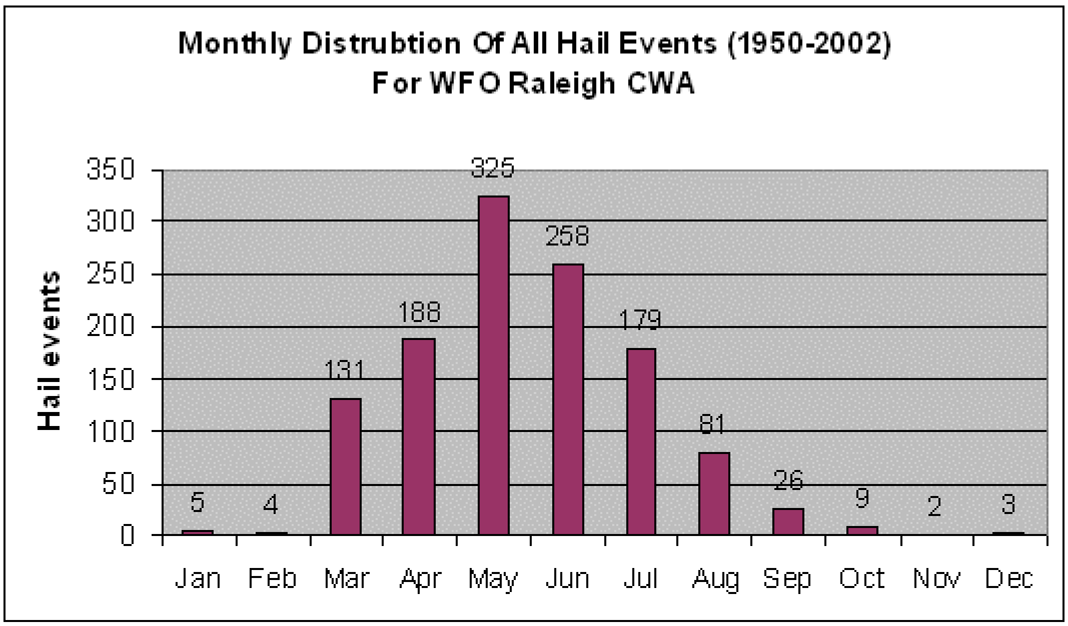

Figure 7: The monthly hail distribution (1950-2002) for WFO Raleigh CWA.

Hourly Distribution

Similar to the hourly tornado distribution, there is a dramatic increase in severe hail after the noon hour (Fig. 8). 783 severe hail events of the 1211 total occurrences (65%) were during the hours of 3 PM to 8 PM. A steady decline of severe hail occurrences was indicated during the late afternoon and evening hours. Severe hail was rare overnight and during the morning. The peak occurrence of hail frequency during the early-to-mid afternoons can be attributed to several factors. The natural evolution of thunderstorms in which updrafts of the storm are strongest is during the formative or initial stage. Strong updrafts are more favorable for hail formation. Secondly, as was the case for tornadoes, is atmospheric instability. Atmospheric instability is maximized during the afternoon.

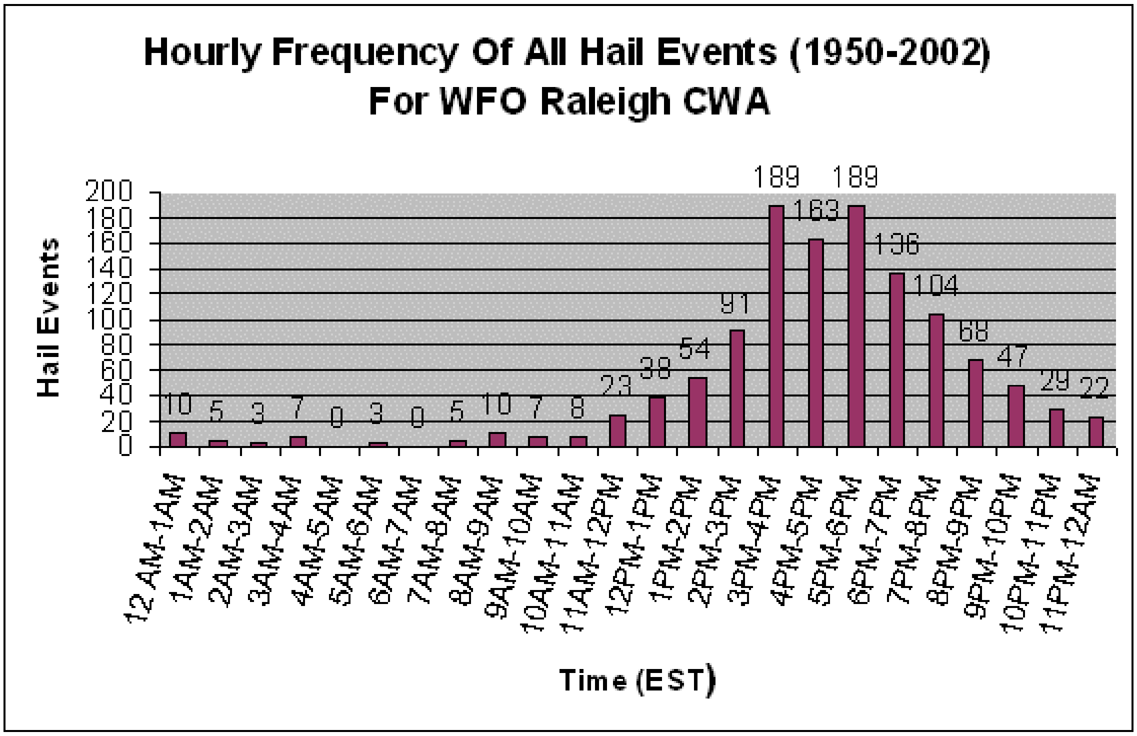

Figure 8: The hourly hail distribution (1950-2002) for WFO Raleigh CWA.

Magnitude (Hail Size)

Nearly half of severe hail reported (595 events or 49% of the total) in the Raleigh CWA was less than one-inch diameter (Fig. 9). Occurrences of hailstones ranging from one to two inches accounted for 47% of the reports. Severe hail of over 2 inch diameter accounted for only a small percentage (~4%). The largest hailstone measured in the Raleigh CWA during the period was 4.5-inch diameter. The softball size hail occurred in Montgomery County on May 27, 1998 at 625 pm EST with a non-tornadic supercell thunderstorm.

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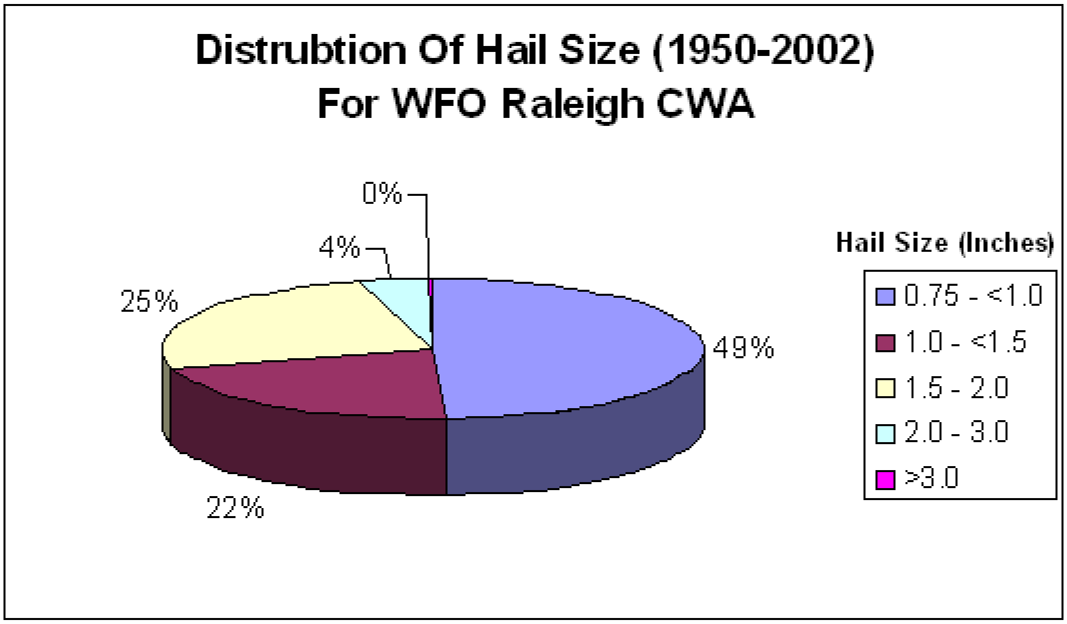

Figure 9: The size distribution of hail events (1950-2002) for WFO Raleigh CWA.

Severe Thunderstorm Damaging Wind Climatology

Monthly Distribution

Strong, damaging winds resulting from severe thunderstorms, fast moving squall lines or bow echoes are the most frequent severe weather event across the Raleigh CWA. Over the 52-year period between 1950 and 2002, there were 2119 severe thunderstorm wind events (60% of all severe events). Severe thunderstorm damaging wind events from convective storms show a steady increase during the spring and peak in June (Fig. 10). Nearly one quarter of the severe thunderstorm damaging wind events (23% or 488 events of the total) occurred in June. During the late spring and early summer months of May, June and July, 1268 events (60%) occurred.

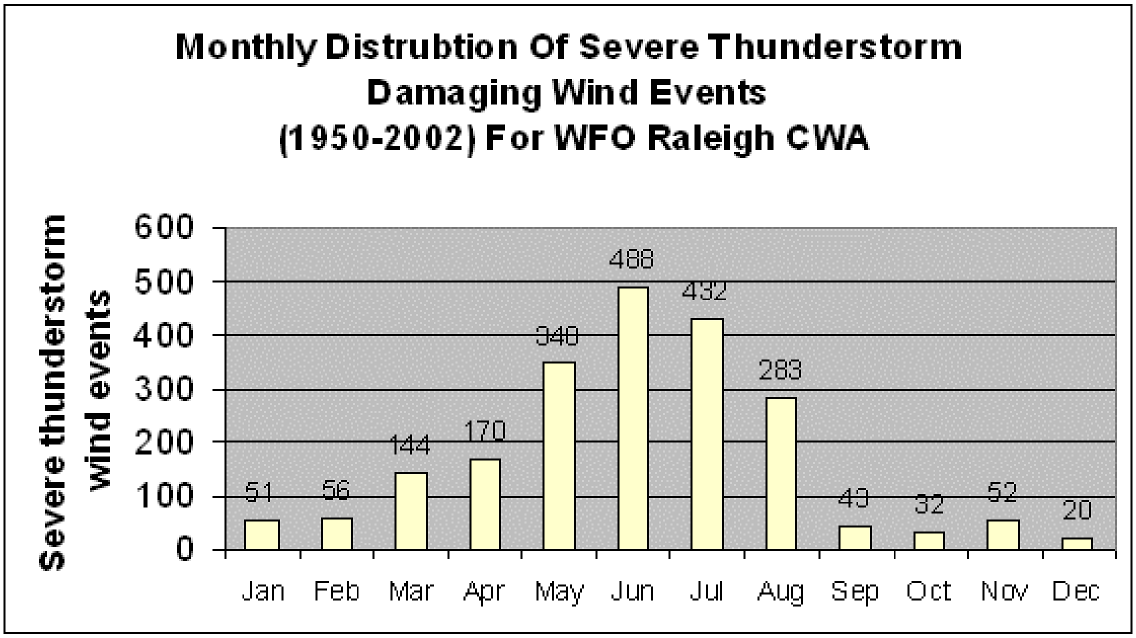

Figure 10: The monthly distribution of severe thunderstorm damaging wind events (1950-2002) for WFO Raleigh CWA.

Hourly Distribution

Thunderstorm wind damage is most common during the mid-afternoon through evening hours (Fig. 11). Although thunderstorm wind events peak between 4 PM and 7 PM, they do not decline significantly until after 9 PM, when the impact of daytime heating on atmospheric instability is lost. The majority (75 %, 1597) of all thunderstorm wind events occur during the 2 PM to 9 PM time frame. Severe thunderstorm damaging wind events drop off significantly between 3 AM and 8 AM. However, thunderstorm wind events may occur during any hour of the day.

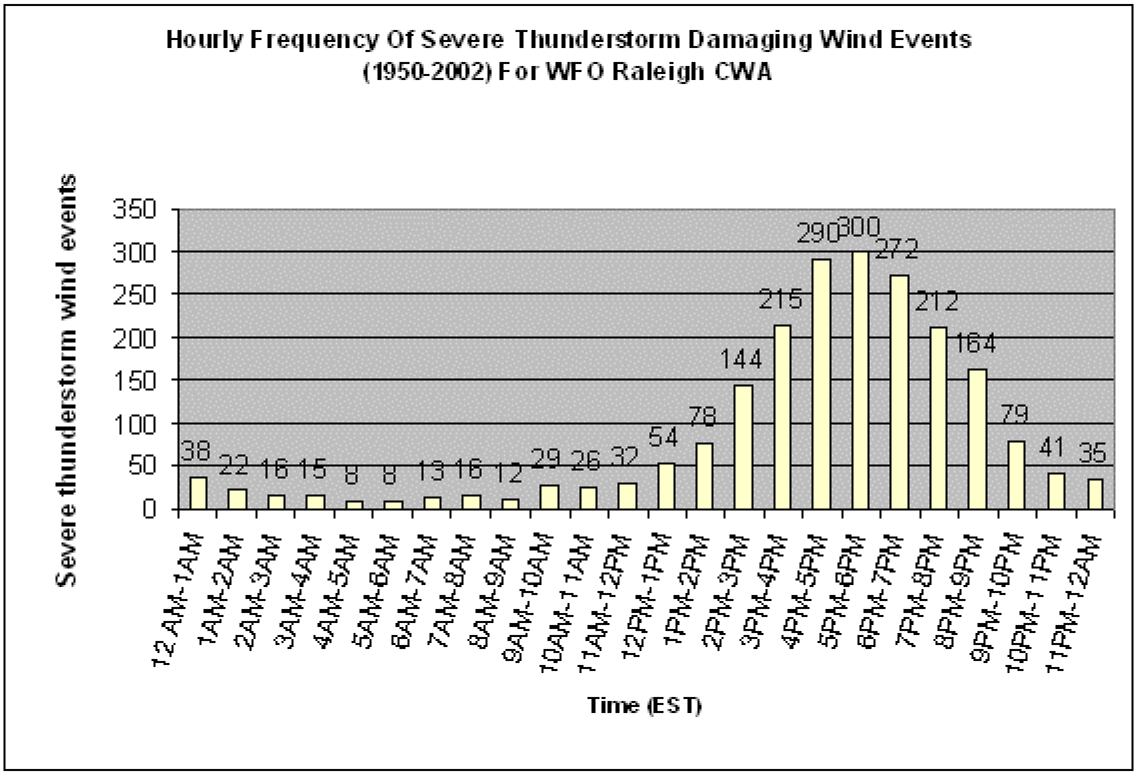

Figure 11: The hourly distribution of severe thunderstorm damaging wind events (1950-2002) for WFO Raleigh CWA.

CONCLUSION

The severe weather climatology for WFO Raleigh CWA provides a historical database that is a resource for both forecasters and weather users. Knowing the frequency of severe weather events relative to the topographic, demographics, time of year and time of day considerations heightens an awareness of the relative risk of severe weather events for the general public and is a key consideration for meteorologists making severe weather warning decisions. A summary of some of the study's more notable findings include the following:

- While tornadoes can and do develop at any time of the year, the majority of tornadoes (60%) occur between March and June, peaking during the month of May.
- A secondary peak for tornadoes occur in the fall associated with the inland effects from tropical cyclones and from the influence of synoptic scale storm systems associated with seasonal migratory upper level jet stream.
- Over half (56%) of the tornadoes occur between the afternoon hours of 3 PM to 8 PM (EST) with the activity peaking between 5 and 7 PM.

- Nearly 75% of all tornado events were classified as weak tornadoes (F0 or F1) and only 5 tornadoes (2%) of F4 intensity have been reported. There have been no reports of tornadoes rated as F5 intensity.
- 78% of severe hail events occurred between April and July with 65% of severe hail events observed during the hours of 3 PM to 8 PM.
- Almost half (49%) of all severe hail reports are less than one-inch diameter (quarter size).
- Severe thunderstorm damaging winds are the most frequent severe event (60%) across the Raleigh CWA.
- Over half (60%) of all thunderstorm damaging wind events occur in the late spring and early summer months of May, June and July, peaking in June.
- A large majority (75 %) all thunderstorm damaging wind events occur during the 2 PM to 9 PM time frame, peaking between 4 and 7 PM.
- Counties with a higher population density are more likely to report more events. Low population density counties are more likely to have events that are not witnessed firsthand and therefore go unreported.

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